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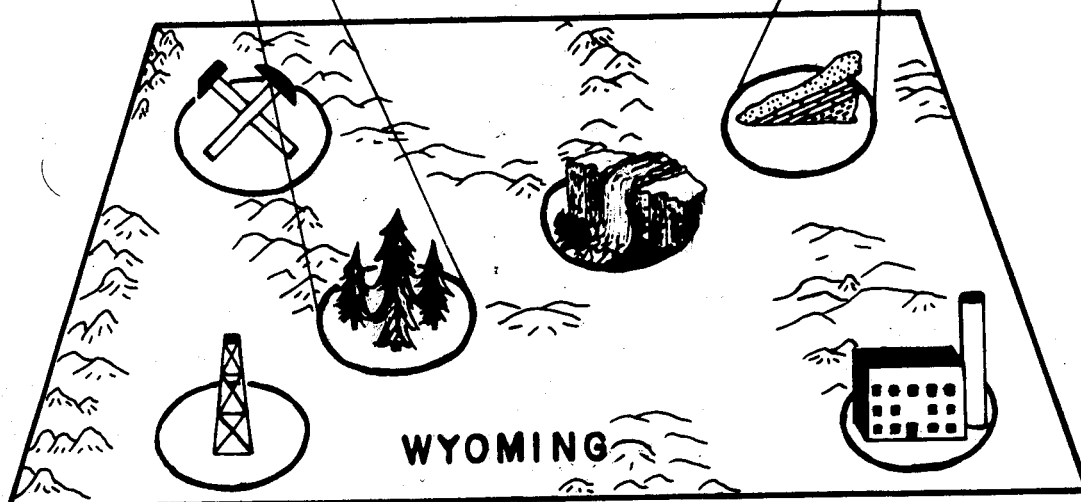
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RONALD W. MARRS

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ANALYSIS OF ERTS IMAGERY OF WYOMING AND ITS APPLICATION TO EVALUATION OF
WYOMING'S NATURAL RESOURCES

Ronald W. Marrs
Department of Geology
University of Wyoming
Laramie, Wyoming 82070

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PREFACE

This first summary report for the University of Wyoming ERTS-1 investigation reports the progress of that investigation from July, 1972, through December, 1972. Many of the results discussed in this summary have been previously detailed in the Type 1 reports (Houston and Marrs, Sept., 1972 and Nov., 1972) and in special reports (Blackstone, Nov., 1972 and Parker, Dec., 1972). Previously reported items will be summarized very briefly in this report, while progress since the November Type 1 report will be discussed in some detail.

TABLE OF CONTENTS

Introduction	1
Investigation Progress	1
Conformance with Work Schedule	10
Explanation of Problems	11
Adequacy of Funds	12
Personnel	13
Planned Work for Next Report Period	14
Significant Results	14
Cooperation with State Agencies	16
References	18

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16. Abstract <p>The University of Wyoming ERTS investigation is proceeding smoothly toward successful completion of its goals. Work has already begun on most of the tasks outlined in the proposal. The remaining tasks are scheduled to begin before June, 1973. Funds have generally been adequate and the only major hindrance has been the lack of some needed data items.</p> <p>Significant results of the Wyoming investigation during the first six months include 1) successful segregation of Precambrian metasedimentary/metavolcanic rocks from igneous rocks, 2) discovery of iron-formation within the metasedimentary sequence, 3) mapping of previously unreported tectonic elements of major significance, 4) successful mapping of large-scale fractures of the Wind River Mountains, 5) successful distinction of some metamorphic, igneous, and sedimentary lithologies by color-additive viewing of ERTS images, 6) mapping and interpretation of glacial features in western Wyoming and, 7) development of techniques for mapping small urban areas.</p>			
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INTRODUCTION

Objectives of the Wyoming ERTS-1 investigation include the application of satellite imagery to geologic mapping, the study of agricultural and botanical features and their distribution, hydrologic studies, land-use studies, and natural resource inventories. Work has begun on various aspects of each of these major objectives during the first six months of the Wyoming ERTS investigation. Some of this early work has already produced significant results with respect to the use of ERTS imagery and the relationships between and importance of large-scale features which can be seen on the ERTS imagery.

This report reviews the Wyoming ERTS-1 investigation for the first six months. Progress in the past two months (November-December, 1972) is presented in detail because it has not been discussed in previous reports.

The tasks that have been completed or are now underway are reviewed or discussed and then compared to the program objectives outlined in the proposal.

INVESTIGATION PROGRESS

Work Summary

The first ERTS imagery was not received until early September, 1972, so the first two months of the program were devoted to analysis of aircraft data from ERTS support flights and to equipping the laboratory to receive and process ERTS data.

A limited amount of both high- and intermediate-altitude aircraft photography (Mission 184 and U-2 flight 71-052) has been available from

the outset of the program. This photography includes color, color infrared, and multiband photography for small portions of several of the Wyoming test sites. Analysis of this photography has not only produced valuable interpretive data, but allowed the scientists to familiarize themselves with remote-sensor data and interpretation techniques. By the time ERTS imagery became available, most of the Wyoming investigators had chosen particular areas and problems with which to begin their analysis. Some had already begun collecting ground-truth data for later correlation with the imagery interpretations.

We have received ERTS imagery at regular intervals since September, 1972, but none of the data shipments conform precisely to our standing order. All are deficient in one way or another and the deficiencies are seldom made up in later data shipments. As a result, our analyses are often hindered by lack of complete data sets. In some instances we lack images in the proper format for a given type of analysis, and in other instances, we lack one or more bands of an ERTS image set.

In a recent attempt to correct this situation (Dec. 4, 1972) we compiled a complete inventory of the data we had received to that time. This information was sent to the scientific monitor along with a request to have the missing items supplied. As yet, we have not received any of the data so requested.

An intermediate-altitude aircraft flight (NASA Mission 213) was flown Sept. 9-10, 1972, to obtain detailed data in support of the Wyoming ERTS investigation. This flight was very successful. Practically all of the requested coverage was obtained and ground crews were able to gather the

necessary ground truth and calibration data. Transparency duplicates of the aircraft data were received less than two months after the mission was flown.

The scope of the Wyoming ERTS investigation is such that investigators are allowed considerable latitude with respect to specific test areas, problems, and techniques. Thus, each investigator was allowed to choose a problem and test area from a broad range of applications, and proceed with his analysis by whatever means the problem required.

The University of Wyoming investigators have at their disposal a remote-sensing interpretation laboratory equipped with: 1) standard photointerpretation devices including a Richards 940-series light table with zoom microscope for non-stereo imagery interpretation and a Richards MIM-3 interpretation table with a zoom stereo-microscope for stereo image interpretation, 2) a Spectral Data model 62 color-additive viewer for forming false-color composites and for color-additive enhancement of multispectral images, 3) a Bausch and Lomb zoom transfer scope for accurate transposition of data from imagery to maps, and, 4) a Tech Ops model 608 Isodensitracer which provides accurate image-density measurements and density contour maps of the images. This equipment combination provides the investigators with excellent capability for standard photointerpretation and the additional capability to enhance either color contrasts or brightness contrast to the limit of the film resolution.

For more quantitative analysis, the Wyoming investigators have access to the Xerox Sigma-7 computer which presently provides two 7-track tape drives, 37.5 million words of disc storage, and a 50-thousand-word working core. The system will soon be updated to provide four tape drives and a 128-thousand-word core-capacity.

A considerable array of ground truth equipment is available to the Wyoming investigators allowing them to make quantitative determinations of spectral reflectances, to simulate ERTS multiband imagery or other photographic bands, and to monitor surface and atmospheric conditions. This data can be gathered independently or in conjunction with a satellite or aircraft overpass and can be used either to calibrate the imagery, or simply to aid in interpretation.

Dr. R. S. Houston, the principal investigator, began his ERTS studies with an attempt to map units within the previously undifferentiated sequence of Precambrian metavolcanic metasedimentary and igneous rocks of the Sweet-water Mountains. His effort included analysis of high- and intermediate-altitude aircraft photography in addition to the ERTS imagery. Thus, he was able to make a comparison among the various types of data that were available and arrive at a better assessment of the utility of the ERTS imagery.

Dr. Houston experienced considerable success in his mapping of Precambrian units, and, as a consequence, produced some useful results. Interpretation of the intermediate-altitude aircraft data (which was available for only part of the area) and subsequent field checks demonstrated that a very accurate geologic reconnaissance map could be prepared by photogeologic interpretation of the intermediate-altitude photography. Thus, the intermediate-altitude photography was useful as a data base against which to compare the interpretations of high-altitude photography and satellite imagery. In addition the field studies revealed that one of the mappable

Precambrian units, the metasedimentary sequence, contains several bodies of taconite which could be of economic significance (Houston and Marrs, Nov., 1972, p. 3). Dr. Houston has since succeeded in distinguishing areas of metasedimentary/metavolcanic terrain from areas of granite igneous terrain using the ERTS imagery. Thus, he is able to map units within the Precambrian lithologic sequence, and, in so doing, he can locate the areas where taconite is likely to be found.

Progress in this work has been reported in the previous Type 1 reports (Houston and Marrs, Sept., 1972 and Nov., 1972) and a special report on this effort is now in preparation.

Dr. D. L. Blackstone applied ERTS imagery interpretation to a tectonic analysis of the Rock Springs Uplift and vicinity. One of the most significant results of this work was the location of two previously unreported linear elements which Dr. Blackstone interprets as surface expressions of deep-seated structural elements. In addition to these previously unrecognized features, many known tectonic features can be recognized and mapped. Dr. Blackstone's work emphasizes the advantages of the ERTS imagery in synoptically displaying an entire array of large-scale tectonic features so that their interrelationships can be seen. As a result, the block-like pattern of major structural elements in the Rock Springs area was confirmed. Details of this work are discussed in a special report recently submitted to NASA (Blackstone, Nov., 1972).

Dr. R. B. Parker has undertaken an analysis of the large-scale fracture systems in the crystalline rocks of the Wind River Mountains using ERTS and aircraft imagery. He first used the aircraft photography to make a

detailed fracture interpretation for a small portion of the area. He then made a similar interpretation for the entire Wind River Range using the ERTS imagery. Comparison of the two interpretations and the limited field checks indicate that the ERTS imagery can be used successfully as a means of mapping these large fracture systems rapidly and accurately. This is a particularly valuable capability in areas such as the Wind River Mountains where so little of the geology is presently known.

Dr. Parker has submitted a special report which summarizes his work with the ERTS imagery of the Wind River Mountains (Parker, Dec., 1972). With the encouraging results from this initial work, Dr. Parker will continue his analysis of these fracture systems.

Dr. Parker and Dr. Houston have undertaken a joint effort to use the ERTS imagery for mapping various sedimentary, metamorphic, and igneous rocks. They have had considerable success with standard photointerpretation techniques in situations where the rock-types are represented by strongly contrasting tones. In more difficult situations where the tonal contrasts are subtle, color-additive viewing has been of some assistance yet many of the lithologic contacts which are expressed as subtle tonal contrasts are not apparent on any of the ERTS bands and are not enhanced by color-additive techniques. Further investigation of successful and unsuccessful attempts at multispectral enhancement suggests that the differentiability of lithologic units is related to iron and iron oxide content of the rock units.

L. C. Rowan (1972) of the U.S. Geologic Survey has researched this problem using aircraft multiband photography. His results (p. 60-1) also indicate that contrasts enhanced by multiband techniques are related to iron oxide content. R. K. Vincent of Environmental Research Institute of Michigan, is presently researching a ratioing method which exploits these iron

oxide differences as a means of mapping certain lithologies with ERTS data (1973, personal communication). Results of the Wyoming studies concerning the relationships between iron content and energy return recorded on bands 5 and 7 are in agreement with Rowan's findings, but a few lithologies do not appear to fit this pattern. These discrepancies could be significant either as hindrances or aids in making lithologic distinctions. In either event, further work is needed to discover the cause of the apparent discrepancies and their significance.

Mr. R. W. Marrs, the Wyoming project coordinator, and Mr. Roy Breckenridge are using the ERTS imagery to map cultural development, land use, and land-use potential. This effort includes photo-mapping of urban areas, areas of agricultural development, hydrologic features, mineral development, soils, and rocks.

Mr. Marrs and Mr. Breckenridge have recently achieved considerable success in the mapping of urban areas using the isodensitracer as a tool for contouring small areas of subtle tonal contrast. This success has allowed them to develop a technique for monitoring urban development with ERTS imagery. This technique is discussed more fully in the "Significant Results" section of this report.

Detailed tonal information derived with the aid of the isodensitracer can be combined with information derived by standard photointerpretation and color-additive enhancement to yield information about cultural patterns and natural features which control or influence these patterns. Because many of the natural features are interrelated and exert a controlling influence on the cultural development, all of the natural and cultural features detectable on the imagery can be treated as an interrelated data array.

Therefore, it is possible to combine the geological, geomorphological, hydrological, agricultural, and cultural interpretations to produce a fairly comprehensive land use map.

This portion of the Wyoming ERTS investigation is far from complete, but preliminary results have been very encouraging. A special report on the urban mapping is presently in preparation.

Mr. Breckenridge is also continuing his geomorphologic studies of the ERTS imagery for western Wyoming. These include studies of erosion cycles, mass movements, and glacial geomorphology. The glacial interpretations of the ERTS imagery for western Wyoming are now being completed. The work has been fairly successful, but results are not consistent for all areas. In some areas the maximum extent of glaciation could be interpreted from the ERTS images and some of the glacial deposits could be mapped. In other areas the glacial landforms have been eradicated by subsequent erosion and mass movement, and many of the glacial features are no longer recognizable.

Mr. Marrs has recently been experimenting with color-additive composites of the ERTS images made with diazo color print material as described by W. E. Wildman of the University of California (Oct. 16, 1972). This technique appears very promising as an inexpensive way to construct color composites and, with the appropriate techniques it can be used as effectively for color enhancement as a color-additive viewer. The method has the additional advantage that the product is a hard-copy image. The major disadvantage in the system is that the scale of the individual bands can not be easily adjusted to allow for perfect registration across the entire frame.

During the past academic semester (August-December, 1972) Mr. Marrs taught a senior-graduate level course in remote sensing which was attended

by several of the project investigators and interested students. The course was designed to acquaint the student with the fundamental theory, equipment and practice of remote sensing, so that he might gain a better appreciation for the capabilities and limitations of present day techniques and would be capable of using some of the more fundamental techniques.

Mr. Francis Redfern, a research assistant in Botany with the Wyoming investigation is trying to define various plant assemblages of the Medicine Bow Mountains using the ERTS imagery. His study encompasses both forests and grasslands along with intermediate plant communities. He uses both the aircraft imagery and field studies to define the mappable communities. Subsequent interpretations of ERTS images are then compared to the aircraft photography and ground data to establish the significance of units mappable with ERTS.

Mr. Redfern's study has been somewhat hampered by the lack of cloud-free imagery for the Medicine Bow Mountains and insufficient data with regard to season. The Medicine Bow area has been cloudy during each of the first three ERTS passes and the area has been snow covered during all succeeding passes. Mr. Redfern has been able to derive some useful information from the cloudy ERTS images by color-additive viewing and interpretation in areas between clouds. However, his investigation requires good imagery for at least two seasons including the early growing season (May-June). We are still hopeful that the necessary data can be obtained during the spring and summer, 1973. If not, it may be necessary for Mr. Redfern to choose another test area where the required data is available.

The various programs outlined above embrace almost all specific objectives set forth in the Wyoming Proposal. The only portion of the proposed investigation to which we have not yet directed a concerted effort is that of hydrologic studies, and these have not been completely neglected. In the course of our geologic and land-use studies we have dealt with some of the hydrologic problems. For example, we have determined that snow-cover is readily mappable. But, we have not yet arrived at a method for estimating the moisture content of the snowpack. Lakes, reservoirs and ponds are usually very easy to map and their lateral extent can be monitored quite accurately. However, this allows only a very rough estimate of changes in water volume. We have not been able to measure the very small ponds which can be detected on the ERTS images (as small as 1 acre) because the system resolution does not allow sufficient definition of the pond boundaries. These difficulties are further compounded in areas where lakes and ponds support vigorous plant growth or algal blooms at certain times.

We have not yet succeeded in detecting most types of water pollution. Sediment plumes in large water bodies are often visible and changes in water quality that effect algal or plant growth may be detected during the appropriate seasons.

CONFORMANCE WITH WORK SCHEDULE

Phase I (Data Analysis Preparation) and Phase II (Preliminary Data Analysis) of the Wyoming ERTS program are complete. Type I reports and the revised Data Analysis Plan have been submitted as required along with several special reports concerning particular application.

We are presently involved in Phase III (Continuing Data Analysis) of the Wyoming investigation, and most of the individual programs are progressing smoothly. Consequently, we have been able to make up a portion of time lost early in the investigation when satellite imagery was not available. All investigators should be prepared to take full advantage of the 1973 field season (May-August). It is anticipated that the requested data products that have been omitted from the various data shipments will be received by that time.

EXPLANATION OF PROBLEMS

The program has been hindered from the beginning by lack of appropriate ERTS data products. During the first two months of the investigation (July and August, 1972) no ERTS data were received. Since that time, partial shipments of the requested bulk data have been received at regular intervals. The data received have generally been of acceptable quality and has fulfilled most of the needs of the investigation. But, each of the Wyoming investigators has been hindered in one way or another by the lack of certain data products needed for his investigation. We have continually stressed the need for a complete suite of data for each usable image of the Wyoming test site, but data shipments continue to be incomplete in one way or another and we have not been successful in obtaining the missing items.

A minor problem has been that of data quality. Most of the imagery received from the Goddard Data Center has been of high quality, particularly the positive transparencies. However, many of the 9 in. x 9 in. black and white prints received are poorly exposed, and some appear to be slightly out of focus. All of the 70 mm negatives received to date are too dense

to be readily reproduced with standard photo-reproduction techniques. The excessively long exposure times required for enlargement printing of these negatives make it impossible to produce a sharp, high quality image with standard enlarging equipment.

We are still of the opinion that the lack of high-quality, hard-copy color composites is a serious deficiency. We have been able to use the color composites constructed with the color-additive viewer and/or ozalid color composites to enhance various color anomalies, and in many instances we find that the standard false-color infrared presentation of the image suite provides much of the necessary color discrimination and is far more efficient than interpretation of individual bands. Comparison of color composites produced with the color-additive viewer and diazo technique with a color composite of the Yellowstone area recently received from NASA/Goddard demonstrates that the quality and interpretability of the composite produced at Goddard is far greater than those produced by either of these other techniques.

ADEQUACY OF FUNDS

Throughout the first six months of the Wyoming investigation, expenditures have been kept within the budgeted limits and we foresee no real problem throughout the remainder of the study period. However, our expenses for photographic reproduction have been somewhat higher than anticipated, mainly because our investigation has required that we photographically reproduce imagery for specific applications. The need for much of this special work would be eliminated if all data products specified on our standing order

were provided and if color composites could be obtained. As yet, this special photographic work has not greatly effected the overall budget.

PERSONNEL

Co-investigators who have been actively involved in the Wyoming project during the past six months include Drs. D. L. Blackstone, R. B. Parker, D. H. Knight, and H. G. Fisser of the University of Wyoming and Dr. N. M. Short of the NASA/Goddard Space Flight Center. Other co-investigators who are scheduled to contribute to the investigative effort during the next six months are Drs. E. R. Decker, and L. E. Borgman of the University of Wyoming and Mr. Harold Mathews who has recently joined Dr. Short at NASA/GSFC.

Dr. R. S. Houston, the principal investigator, has provided the administrative leadership for the entire program and has personally undertaken an important part of the geologic investigation.

Mr. Ronald Marrs, the project coordinator, and Mr. Roy Breckenridge, a research associate, are the only full-time investigators on the Wyoming project. They coordinate the research effort, provide technical assistance to the other investigators, and perform individual research projects within the scope of the investigation.

Mr. Francis Redfern, a graduate student in Botany who joined the program in August, 1972, has been the only research assistant participating in the program during the first six months. In January, 1973, a second research assistant, Mr. Robert Gordon, will be added to the program. Mr. Gordon is a graduate student in Plant Science at the University and will be investigating the applications of ERTS to range management.

PLANNED WORK FOR NEXT REPORT PERIOD

Phase III analysis will continue throughout the next report period (January-June, 1973). Laboratory analysis will continue in all phases of the investigation including those which are not yet begun. Multi-season satellite imagery should soon be available and allow greater progress toward vegetation distribution studies, land-use evaluations, and hydrologic analysis. Toward the end of the report period the emphasis will be placed on field work which should provide the necessary control for the imagery interpretations.

SIGNIFICANT RESULTS

Significant results of the Wyoming ERTS investigation which have not been previously reported include results of the glacial landforms mapping of Mr. Breckenridge and marked progress in urban mapping as part of the land-use study undertaken by Mr. Marrs and Mr. Breckenridge.

Mapping of glacial features from ERTS imagery has allowed Mr. Breckenridge to estimate the maximum advance of Pleistocene glaciers for a large part of western Wyoming. Recognizable glacial features include cirques and U-shaped valleys, moraines, outwash, and large-scale glacial "grooves". Throughout most of western Wyoming these Pleistocene features have not been destroyed by subsequent erosion, but in the Absaroka Range of northwestern Wyoming Recent geologic activity has produced geomorphic instability on a grand scale. Consequently, mass wasting and accelerated erosion of volcanic rocks have destroyed many of the Pleistocene glacial features. The interpretability of the glacial geomorphology of the area is severely limited by this loss of data, but, at the same time, the area offers a unique opportunity to observe and study the processes that are destroying the glacial features.

Early attempts to map urban areas in Wyoming using ERTS data were unsuccessful (Houston and Marrs, Nov., 1972). However, subsequent efforts using the isodensitracer as a tool for increasing the scale of the imagery and enhancing subtle tonal contrast has proven remarkably successful.

The technique was first used successfully in mapping urban areas surrounded by open rangeland. The moderate grey-tones of the urban areas contrast sufficiently with the very light tones of the rangeland on the red band ERTS imagery to allow the urbanized area to be separated from the surrounding rangeland. Furthermore, it was discovered that subtle contrasts within the urban areas could be contoured with the isodensitracer, allowing distinction to be made between residential, industrial, and unimproved areas within the urban area.

Urban areas completely or partially surrounded by agricultural lands proved considerably more difficult to map when the regular pattern of agricultural development is broken up by piecemeal development in a zone surrounding the urban area and the tonal contrasts within the agricultural area cover a broader range than those within the urban areas. Such an area was successfully mapped using the combined isodensitracings of both the red and infrared (band 7) ERTS images. Neither of the bands could be used independently to segregate the urban area because, with the red-band image, the urban area merged with the grey tones of the surrounding agricultural area and, on the infrared image, the urban area could not be distinguished from the grey tones of the surrounding farm land. However, isodensitracing of each band at the same scale provided the necessary enhancement of tonal contrasts so that the two isodensitracings could be combined as a composite isodensitracing which allowed the urban area to be separated from the surrounding area.

Some urban areas in Wyoming lie within a complex setting. Laramie, for example, is surrounded by rangeland and agricultural land, all of which is transected by the Laramie River which has a floodplain different from both the range and the farm land. In this complex setting Laramie could not be successfully mapped by either of the techniques described above. In this case, we were fortunate to have a second image of Laramie in which the entire area was snow covered. The snow-cover masked all the interfering tonal contrasts in the surrounding agricultural and rangeland and allowed for very easy mapping of the urban area. Furthermore, the isodensitracing of the city, revealed tonal gradations reflecting melting or disruption of the snow-cover. Consequently, the isodensitracing represents a pseudo-thermal map which, in the case of Laramie, reflects development and intensity of human activity.

A more detailed discussion of the techniques used in these investigations, and the results of both the glacial geomorphologic and urban mapping will be presented in special reports. Both of these special reports should be completed within the next report period.

COOPERATION WITH STATE AGENCIES

Meetings between Wyoming investigators and representatives of various state agencies has precipitated considerable interest in the application of remote-sensing techniques to various agency functions. Discussion of various problems to which remote-sensing methods might apply served to acquaint University investigators with the need for direct application of remote-sensing data to real problems and stimulated interest among the state agencies to investigate remote-sensing techniques as tools for solving some of these

problems. As a result, the Wyoming Department of Economic Planning and Development in cooperation with the University launched a pilot study to evaluate the ERTS imagery as an aid in land-use mapping and land-use potential. The pilot study was highly successful and it is anticipated that the Department of Economic Planning and Development will enter with the University in a proposal to apply the ERTS-B satellite data to regional land-use planning in the state of Wyoming.

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